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Yellows-Resistant Cabbage Varieties in the Danish Ballhead-Hollander Group

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United States Department of Agriculture, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, in cooperation with the Wisconsin Agricultural Experiment Station

CONTENTS

INTRODUCTION

In many districts where cabbage is grown in the United States, yellows, incited by *Fusarium oxysporum* f. *conglutinans* (Wr.) Snyder and Hansen, has become so prevalent that resistant varieties have largely replaced nonresistant ones. The first selections for yellows resistance were made by Jones and Gilman (*3*).[4] In 1916 they introduced Wisconsin Hollander, the variety that has become a standard and is widely used in many areas. In the course of its selection from resistant individuals of Danish Ballhead it became distinct in type. It is some 2 weeks later in maturing than the parent variety and produces taller, larger plants and larger, more flattened heads (*2*).

Soon after the introduction of Wisconsin Hollander, Bugner, a second resistant variety selected in Cook County, Ill., by a local gardener, came into use under the name of the introducer. It has much in common with Wisconsin Hollander but is sufficiently different to warrant distinction as a separate variety.

To meet needs arising for a resistant variety closer to Danish Ballhead in time of maturity and in plant and head type, Walker

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Blank (*7*) started a new series of selections from that variety in 1927. This culminated in a strain introduced in 1935 as Wisconsin Ballhead. This variety resembles Danish Ballhead much more closely in season and in plant and head characteristics than does Wisconsin Hollander.

Anderson (*1*) learned that the resistance of Wisconsin Hollander behaves as a quantitative genetic character in which an undetermined number of genes are concerned. As shown by Walker and Smith (*9*) and more recently by Walker and Hooker (*8*), this resistance character is not stable with respect to temperature and is also influenced in its expression by the nutrition of the host. Under high soil temperatures resistance is suppressed and varying percentages of plants succumb to yellows and show gradations in degree of disease development. Bugner contains essentially the same type of resistance as Wisconsin Hollander. Wisconsin Ballhead, on the other hand, was shown by Walker and Blank (*7*) to contain the resistance character controlled by the single dominant gene previously described by Walker (*6*). Walker and Smith (*9*) and Walker and Hooker (*8*) found that this type of resistance is very stable under wide variations in temperature and host nutrition.

In the past 10 years, when it has been in commercial use in many localities, Wisconsin Ballhead has shown some characters which are not entirely desirable. One of these is a tendency to be somewhat earlier in maturing than acceptable strains of Danish Ballhead, in fact somewhat too early for autumn shipping and storage in the Northern States. It tends to burst too readily under good growing conditions. The mature heads assume a yellowish cast as distinct from the bluish one common in Ballhead strains; the bluish color is more desirable from the standpoint of current market preferences.

In order to combine these characteristics in Wisconsin Ballhead and at the same time introduce the single gene for resistance into Wisconsin Hollander, the two varieties were crossed. Selection and backcrossing were continued for several generations along two major lines, one directed toward improvements in Wisconsin Ballhead and the other toward those in Wisconsin Hollander. A new strain which contains distinct improvements over Wisconsin Ballhead has been developed and was tested on a commercial scale in 1944 and 1945. This was released in 1946 to seed-growing organizations for increase and distribution to the commercial trade. It is designated as Improved Wisconsin Ballhead. Selections in the Wisconsin Hollander type are still in progress.

The purpose of this circular is to delineate the salient features in which the several varieties are either similar or distinctive.

COMPARATIVE VARIETAL DESCRIPTIONS

In order that Improved Wisconsin Ballhead may be distinguished from the standard nonresistant Danish Ballhead and from Wisconsin Ballhead, Wisconsin Hollander, and Bugner, in 1944 and 1945 comparative descriptions and in 1945 measurements were made in the vicinity of Madison, Wis., where the breeding work was carried out. Two commercial nonresistant strains of the Ballhead group were used. One of these, designated herein as Danish Ballhead, was chosen from many commercial stocks as closest to the ideal set up for this variety. The other was an authentic stock of Penn State Ballhead, a selection

introduced and described by Myers (*5*). Full descriptions of Danish Ballhead and Wisconsin Hollander have already been published by Boswell and others (*2*).

Days From Transplanting to Maturity

The number of days from transplanting to maturity of the different varieties at Madison, Wis., in plantings made on July 3 from a seedbed sown on May 8, 1945, are given in table 1. Growing conditions were favorable throughout the season. The growing period of course varies with season, soil, and locality. These data, however, give a basis for comparison of the varieties concerned. Under these conditions Wisconsin Ballhead was approximately a week earlier in maturity than Danish Ballhead. In Improved Wisconsin Ballhead the time to maturity has been lengthened to coincide with that of Danish Ballhead. Penn State Ballhead was a week later than Improved Wisconsin Ballhead, Wisconsin Hollander slightly more than 2 weeks later, and Bugner about 3 weeks later.

Tendency to Burst

Inasmuch as varieties in the Ballhead-Hollander group are latest to mature in the northern region and thus desirably stand for varying periods during cool autumn weather before shipment and storage, it is highly important that they should not burst readily, as do many midseason and early types. In this respect Wisconsin Ballhead has a weakness which has been corrected to some degree in Improved Wisconsin Ballhead. In the 1945 trials when the majority of the plants of Wisconsin Ballhead had reached maturity 26 percent had burst. In the Danish Ballhead and Improved Wisconsin Ballhead varieties, only 10 percent and 12 percent, respectively, had burst when most of the plants had reached maturity. The long-standing characteristic of the improved strain was also evident in previous years.

Leaf and Plant Characters

The salient leaf characters of the different varieties are given in table 2. A typical plant of each variety is shown in figure 1. The direction of outer leaves is similar in all varieties. The inner leaves of Wisconsin Ballhead and Improved Wisconsin Ballhead, however, tend to be less erect than those of the other varieties. The leaves of all varieties tend to curve upward along and across the midrib; those of Wisconsin Ballhead are most nearly flat, while those of Improved Wisconsin Ballhead, Penn State Ballhead, and Bugner curve upward most pronouncedly. The leaf surface is most undulate in Wisconsin Hollander. The leaf margins are most undulate in Improved Wisconsin Ballhead. The edges of the leaves in all varieties except those of the inner leaves of Wisconsin Hollander, which are distinctly crenate, tend to be only slightly crenate. The varieties differ little in leaf shape except that the outer leaves of Improved Wisconsin Ballhead, Wisconsin Hollander, and Bugner are more narrowly wedged at the base than those of the other varieties. Ribs are medium in size and in prominence in all these varieties, but those of Improved Wisconsin Ballhead and Bugner are covered with less bloom than those of the other varieties. Veins are most conspicuous in Penn State Ballhead. Bloom on the

TABLE 1.—*Physical measurements (average) on 10 plants and heads each taken at random in parallel plantings of 6 varieties in the Danish Ballhead-Hollander group of cabbage, Madison, Wis., 1945*

Variety	Time from transplanting (July 3) to maturity	Plant		Outer leaves	Weight of—				Part of total above-ground weight in—		Diameter of head			Stem		Core		Polar diameter÷core length	Ascorbic acid in 100 grams
		Width	Height		Outer leaves	Stem	Head	Total (above-ground)	Outer leaves	Head	Polar	Equatorial	Polar÷equatorial	Length	Width	Length	Width		
	Days	*Cm.*	*Cm.*	*No.*	*Gm.*	*Gm.*	*Gm.*	*Gm.*	*Pct.*	*Pct.*	*Cm.*	*Cm.*		*Cm.*	*Cm.*	*Cm.*	*Cm.*		*Mg.*
Danish Ballhead	97	76.9	35.7	14.8	1,472.7	210.8	2,706.4	4,389.9	33.5	61.7	19.0	18.9	1.01	8.0	5.87	13.4	3.96	1.42	59.2
Wisconsin Ballhead	91	75.1	33.5	16.9	1,369.0	223.0	2,841.5	4,433.5	30.9	64.1	18.1	20.1	.90	8.7	6.25	11.8	4.87	1.53	59.3
Improved Wisconsin Ballhead	97	72.8	38.6	15.5	1,625.9	180.7	3,739.5	5,546.1	29.3	67.4	19.6	21.7	.90	7.0	6.50	12.2	4.13	1.61	48.2
Penn State Ballhead	104	82.9	38.7	18.7	2,101.3	190.4	3,500.4	5,792.1	36.3	60.4	18.0	22.8	.79	7.9	5.89	11.1	4.71	1.62	59.7
Wisconsin Hollander	113	87.4	45.5	19.4	2,215.1	386.9	3,303.8	5,905.8	37.5	55.9	18.5	22.7	.81	16.1	5.87	13.1	5.05	1.41	52.7
Bugner	120	87.2	42.5	17.9	2,278.5	345.0	4,611.2	7,234.7	31.5	63.7	20.0	25.8	.78	14.2	5.70	13.8	4.64	1.45	51.6
Least significant difference:																			
5-percent level		5.4	5.0	(1)	356.0	42.1	612.8	849.2	4.0	4.4	1.4	1.4	.07	1.5	(1)	1.3	.35	.11	5.1
1-percent level		7.2	6.6	(1)	475.5	56.2	818.5	1,134.2	(1)	5.9	(1)	1.9	.09	2.1	(1)	(1)	.46	.15	6.8
F value [2]		6.23**	3.51**	2.15	5.72**	19.40**	10.28**	7.02**	3.04*	6.81**	2.88*	22.97**	12.68**	27.97**	1.93	2.85**	6.84**	6.43**	4.97**

[1] No significant difference.
[2] *F* for 0.05=2.42; *F* for 0.01=3.45; * data significant at the 5 percent level; ** data significant at 1-percent level.

DANISH BALLHEAD

PENN STATE BALLHEAD

WISCONSIN BALLHEAD

WISCONSIN HOLLANDER

IMPROVED WISCONSIN BALLHEAD

BUGNER

FIGURE 1.—Typical plants of six cabbage varieties, grown near Madison, Wis.

leaf blade is not quite as heavy in Improved Wisconsin Ballhead as in other varieties, and the color of the blade in that variety is slightly darker blue green than in the others.

Certain other plant and leaf characters are indicated in the physical measurements from the 1945 trials (table 1). Danish Ballhead and Wisconsin Ballhead were not significantly different in plant height. Improved Wisconsin Ballhead and Penn State Ballhead were slightly but significantly taller than Wisconsin Ballhead. Wisconsin Hol-

TABLE 2.—*Leaf characters of 6 varieties of the Danish Ballhead-Hollander group of cabbage, Madison, Wis., 1945*

[Color values according to Maerz and Paul (4)]

Variety	Direction of—			Curvature along and across midrib	Surface	Margin	Edge of—	
	Outer leaves	Middle leaves	Inner leaves				Outer leaves	Inner leaves
Danish Ballhead	Horizontal to slightly drooping.	Curving broadly upward at about 45° above horizontal.	Almost erect	Curving slightly upward.	Nearly smooth to slightly undulate.	Flat to slightly undulate.	Entire to slightly erenate.	Entire to slightly erenate.
Wisconsin Ballhead	do	do	Curving broadly upward at about 60° above horizontal.	Flat to curving slightly upward.	Slightly undulate to undulate.	Slightly undulate to undulate.	do	Do.
Improved Wisconsin Ballhead.	do	Curving upward at 30° to 45° above horizontal.	do	Curving definitely upward.	Smooth to slightly undulate.	Undulate to very undulate.	Slightly erenate to erenate.	Slightly erenate to crenate.
Penn State Ballhead.	do	Curving upward at about 45° above horizontal.	Almost erect	do	Smooth to undulate	Flat to undulate	do	Do.
Wiseonsin Hollander.	do	Curving abruptly upward at about 45° above horizontal.	do	Curving slightly upward.	Undulate	Slightly undulate	do	Distinetly erenate.
Bugner	do	Curving upward at about 45° above horizontal.	do	Curving definitely upward.	Smooth to undulate	Undulate	Slightly erenate.	Slightly erenate.

Variety	Shape of top of—		Shape of base of—		Ribs	Veins	Bloom on leaf blade	Blade color
	Outer leaves	Inner leaves	Outer leaves	Inner leaves				
Danish Ballhead	Rounded	Rounded to broadly rounded.	Wedged	Broadly wedged.	Medium size; medium conspicuous; well covered with bloom; color about 17 C 3.	Not conspicuous; color about 19 C 2.	Very heavy	Mostly about 35 D 2.
Wisconsin Ballhead	do	Rounded	do	Wedged to broadly wedged.	do	Not conspicuous; color about 19 B 3.	do	Do.
Improved Wisconsin Ballhead.	Broadly rounded.	Broadly rounded	Narrowly wedged to wedged.	Wedged	Medium size; medium conspicuous; fairly well covered with bloom; color about 17 D 3.	Not conspicuous; color about 19 C 3.	Moderately heavy.	Ranging from 29 H 1 to 30 H 5.
Penn State Ballhead.	do	do	Wedged	Broadly wedged.	Medium size; medium conspicuous; well covered with bloom; color about 17 B 3.	Conspicuous; color about 19 B 3.	Very heavy	About 37 F 3.
Wisconsin Hollander.	Rounded to broadly rounded.	Rounded to broadly rounded.	Narrowly wedged.	Wedged	Medium size; medium conspicuous; well covered with bloom; color about 17 C 3.	Not conspicuous; color about 17 A 2 or 19 B 3.	do	Do.
Bugner	do	do	do	do	Medium size; medium conspicuous; fairly well covered with bloom; color about 17 B 3.	Medium conspicuous; color about 19 B 3.	do	Do.

lander and Bugner were taller than the other varieties in the group. They also had highly significantly longer stems.

Danish Ballhead, Wisconsin Ballhead, and Improved Wisconsin Ballhead had fewer outer leaves than did Bugner, Penn State Ballhead, and Wisconsin Hollander; but there was enough variation between individuals in each variety to invalidate the significance of differences between mean values. The weights of outer leaves of Bugner, Wisconsin Hollander, and Penn State Ballhead, however, were highly significantly greater than those of Danish Ballhead, Wisconsin Ballhead, and Improved Wisconsin Ballhead. Improved Wisconsin Ballhead was lowest in the percentage of the total aboveground weight contributed by outer leaves; the value was significantly lower than that of Danish Ballhead, Penn State Ballhead, and Wisconsin Hollander.

Head Characters

The head characters of the different varieties are summarized in table 3. Typical heads of each variety are shown in figures 2 and 3. With regard to head shape the varieties fall into two distinct groups. Heads of Danish Ballhead, Wisconsin Ballhead, and Improved Wisconsin Ballhead are nearly spherical, whereas those of Penn State Ballhead, Wisconsin Hollander, and Bugner are definitely flattened. These and certain other differences in head characteristics are given in the form of exact measurements in table 1. The shape of head is expressed as the ratio of polar to equatorial diameter. A perfectly spherical head would have a value of 1.00; values above 1.00 would indicate oblong shape and values below 1.00 would indicate various degrees of flattening. The heads of Danish Ballhead averaged very slightly oblong. Those of Wisconsin Ballhead and Improved Wisconsin Ballhead were slightly flatter than spherical and for each the difference from Danish Ballhead was highly significant. The ratios for Penn State Ballhead, Wisconsin Hollander, and Bugner were not significantly different from one another, but each of these differed highly significantly from those of the first three varieties. The tops of the heads of the three earlier varieties were rounded, whereas those of the three later ones were flattened.

Table 3.—*Head characters of 6 varieties of the Danish*

[Color values according

Variety	Shape	Top	Base	Outer head leaves	Outer ribs
Danish Ballhead	Nearly spherical to slightly oblong.	Rounded	Tapered slightly.	Tight, reaching just past center.	Medium; not conspicuous.
Wisconsin Ballhead.	Nearly spherical.	do	Rounded to slightly tapered.	do	do
Improved Wisconsin Ballhead.	do	do	do	do	do
Penn State Ballhead.	Flattened	Flattened	do	do	Medium to large; not conspicuous.
Wisconsin Hollander.	do	Flattened to slightly rounded.	Mostly rounded.	Tight, reaching well past center.	do
Bugner	do	Flattened	do	Tight, reaching just past center.	do

The color of the heads at maturity is light blue in the Bugner and Wisconsin Hollander varieties and slightly more yellowish blue in the Penn State Ballhead and Danish Ballhead. Wisconsin Ballhead has the objectionable tendency of the top leaves of the head becoming quite yellow as the head matures; this makes the head appear more like one of a midseason variety than one of the Ballhead class. Persistent selection for better color has brought Improved Wisconsin Ballhead to approximately the same color of head as Danish Ballhead and Penn State Ballhead.

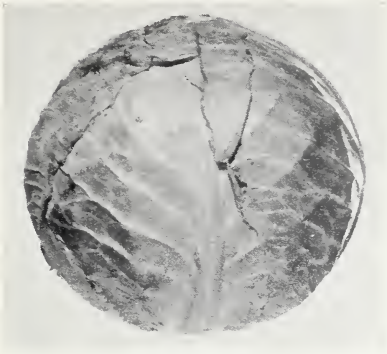
It will be noted that in 1945 at Madison, Wis., the heads of Improved Wisconsin Ballhead were highly significantly heavier than those of Danish Ballhead, which matured at the same time, and heavier, though not significantly so, than those of Penn State Ballhead and Wisconsin Hollander, which matured 7 days and 16 days later, respectively (table 1). In another 1945 trial, near Kenosha, Wis., Improved Wisconsin Ballhead outyielded Wisconsin Ballhead by 46 percent.

The internal head characteristics of the six varieties are illustrated in figure 3. Bugner had the greatest crumpling of the head leaves and Wisconsin Hollander the least compactness, whereas head leaves of Improved Wisconsin Hollander were most compact. In core width, taken midway between the base of the head and the tip of the core, the value for Improved Wisconsin Ballhead was highly significantly lower than that for any other variety except Danish Ballhead (table 1). The core was shorter in relation to the polar diameter of the head (i. e., higher quotient of polar diameter ÷ core length, as shown in table 1) than in any other variety except Penn State Ballhead. The difference in this value was highly significant when compared with the values for Danish Ballhead, Wisconsin Hollander, and Bugner.

In ascorbic acid content the variety means ranged from 48.2 to 59.7 milligrams per 100 grams of fresh tissue at harvest. The varieties fell into two groups, between which the differences were significant. Danish Ballhead, Wisconsin Ballhead, and Penn State Ballhead were in the group higher in acid. Wisconsin Hollander, Bugner, and Improved Wisconsin Ballhead were in the group lower in acid. Thus, Improved Wisconsin Ballhead resembled the Wisconsin Hollander parent in this respect.

Ballhead-Hollander group of cabbage, Madison, Wis., 1945
to Maerz and Paul (4)]

Bloom	Color	Internal structure	Internal leaves	Internal ribs
Medium heavy.	About 21 J 6.	Very compact.	Smooth; closely arranged; relatively little crumpling.	Arising at 30° from base of core; nearly horizontal at center of core.
---do------	About 21 L 7.	-----do-------	Smooth; closely arranged; moderate crumpling.	Arising slightly above horizontal at base; nearly horizontal at center.
---do------	About 21 J 6.	-----do-------	Smooth; closely arranged; little crumpling.	Arising at 30° from base; horizontal at center; at 45° near top of core; core tends to be distinctly narrowed and pointed at top.
---do------	About 21 K 6.	-----do-------	-----do----------	Arising slightly above horizontal at base; slightly drooping above center of core.
---do------	About 21 D 5.	Moderately compact.	Leaves above core smooth and closely arranged; lower leaves slightly crumpled.	Arising horizontally at base; drooping at center of core and above.
---do------	-----do------	-----do-------	Outer leaves smooth; inner leaves crumpled.	Arising slightly above horizontal at base; at 30° or more above horizontal at center and above.



DANISH BALLHEAD

PENN STATE BALLHEAD

WISCONSIN BALLHEAD

WISCONSIN HOLLANDER

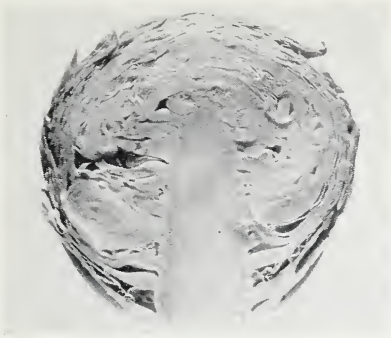
IMPROVED WISCONSIN BALLHEAD

BUGNER

FIGURE 2.—Head types of six cabbage varieties, grown near Madison, Wis.

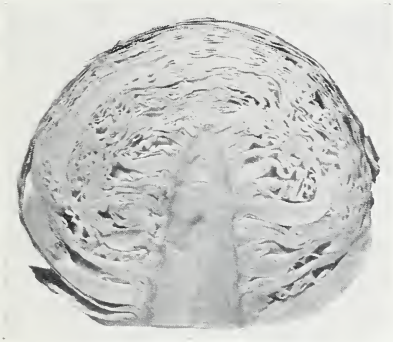
SALIENT CHARACTERISTICS OF IMPROVED WISCONSIN BALLHEAD

In the development of Improved Wisconsin Ballhead certain features undesirable in the Wisconsin Ballhead parent have become less prominent. The season has been lengthened approximately 1 week



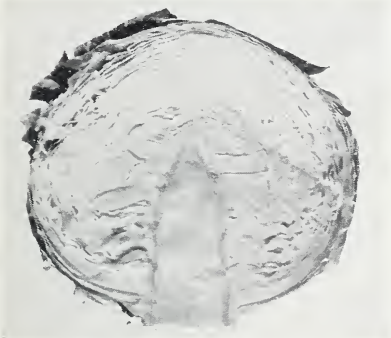
DANISH BALLHEAD

PENN STATE BALLHEAD

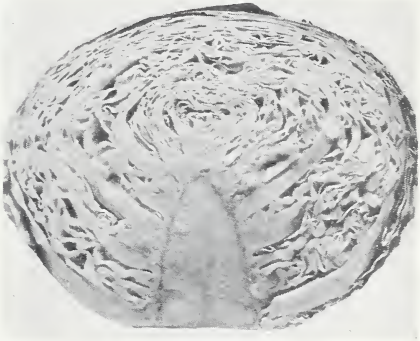


WISCONSIN BALLHEAD

WISCONSIN HOLLANDER



IMPROVED WISCONSIN BALLHEAD



BUGNER

FIGURE 3.—Polar cross sections of heads of six cabbage varieties, grown near Madison, Wis.

to coincide with that of the standard Danish Ballhead parent. The tendency to burst very readily has been reduced. The new variety should therefore be much more satisfactory both for shipping and for autumn storage. The nearly spherical head has been maintained, and the tendency in some strains of Danish Ballhead to produce a considerable percentage of oblong heads has been largely eliminated.

An unusually large head weight in proportion to outer leaf weight has been retained. This is reflected in heavier tonnage production than that of Wisconsin Ballhead. Improved Wisconsin Ballhead has a somewhat narrower core than Wisconsin Ballhead and a somewhat shorter core than Danish Ballhead. The color of the outer head leaves is more like the Danish Ballhead parent than the Wisconsin Ballhead parent.

Improved Wisconsin Ballhead supplements rather than replaces Wisconsin Hollander, which is some 2 weeks later in maturing. When transplanted in mid-June or earlier the latter should outyield Improved Wisconsin Ballhead when autumn weather is continuously favorable. Wisconsin Hollander is not ordinarily suitable for the most northerly cabbage districts because of the length of its growing season. Bugner has a still longer growing season. Penn State Ballhead, Wisconsin Hollander, and Bugner produce decidedly flatter heads than those typical in the Ballhead type. The fact that these varieties often outyield Danish Ballhead and Wisconsin Ballhead in favorable growing districts has given them some preference in markets where shape of head has not caused adverse comment. In seasons favorable to the production of large heads, moreover, these varieties are used extensively for the late kraut pack. Improved Wisconsin Ballhead is quite similar to the Danish Ballhead type as to season, plant type, and head type. It is superior to Wisconsin Hollander and Bugner in resistance to yellows, since it carries the high type of resistance, commonly referred to as type-A resistance, which is controlled by the dominant gene *R* (*6*).

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